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CHAOTIC MOTION IN THE JOVIAN ATMOSPHERE

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Strong nonlinear interactions among unstable waves and the mean flow occur in a simplified quasigeostrophic spectral model of the upper troposphere of Jupiter. The upper boundary of the layer inhibits vertical motion while at the lower boundary perturbations of the potential temperature are not permitted. On an infinite beta plane the forced flow of alternating zones of prograde and retrograde zonal winds, decreasing with height, are linearly unstable, and it is shown that the nonlinear terms stabilize the flow by bounding the growth of the eddies. Explicit viscosity terms are not needed. This does not imply that energy would not cascade to the small scale flow but suggests that the nature of the large scale flow is independent of the viscosity at small scales. Numerical time integration shows the flow to be chaotic but, in some cases, with transient propagating features and meandering zonal flow.

A spectral potential vorticity model of the upper troposphere of Jupiter has been constructed to study the nonlinear behavior of baroclinic flow on an infinite beta plane. The model imposes a basic zonal flow of alternating jets (longitudinal wavenumber 0 and latitudinal wavenumber 1) which decreases in amplitude with height. The vertical velocity is set equal to zero at the upper boundary of the flow layer (the tropopause) and potential temperature perturbations are required to vanish at the lower boundary. The imposed static stability for two different experiments corresponds to Burger number settings of S = 0.5 and 1.0. A schematic depiction of the basic state flow is shown in Figure 1.

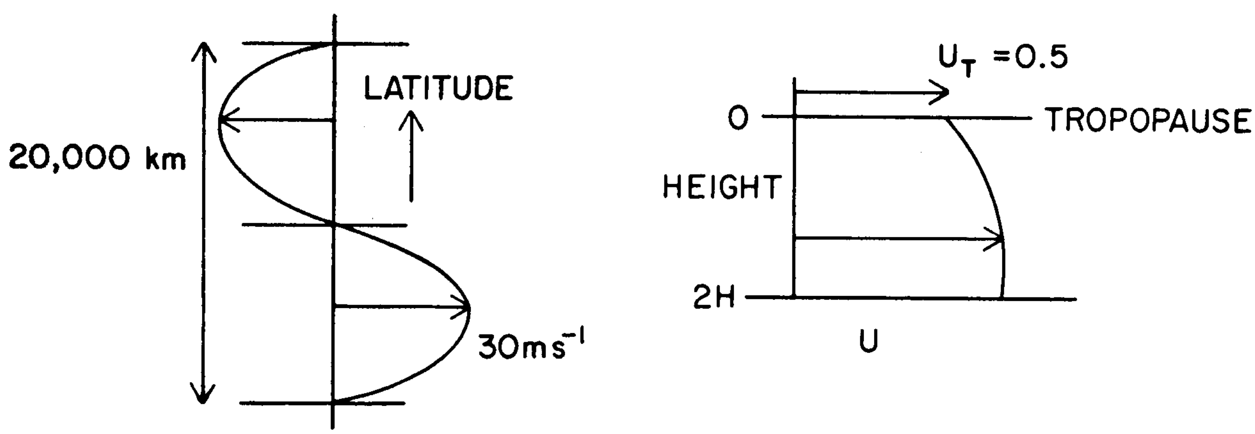

Figure 1. Basic state velocity profile.

The basic state flow is unstable to small perturbations which then grow and interact with the nonlinear terms of the model equations. Figure 2 displays contour plots of the evolving stream functions for the case of S = 1.0 at two different times separated by approximately 6 days. Figure 3 displays stream functions for the case of S = 0.5 at two different times again separated by 6 days.

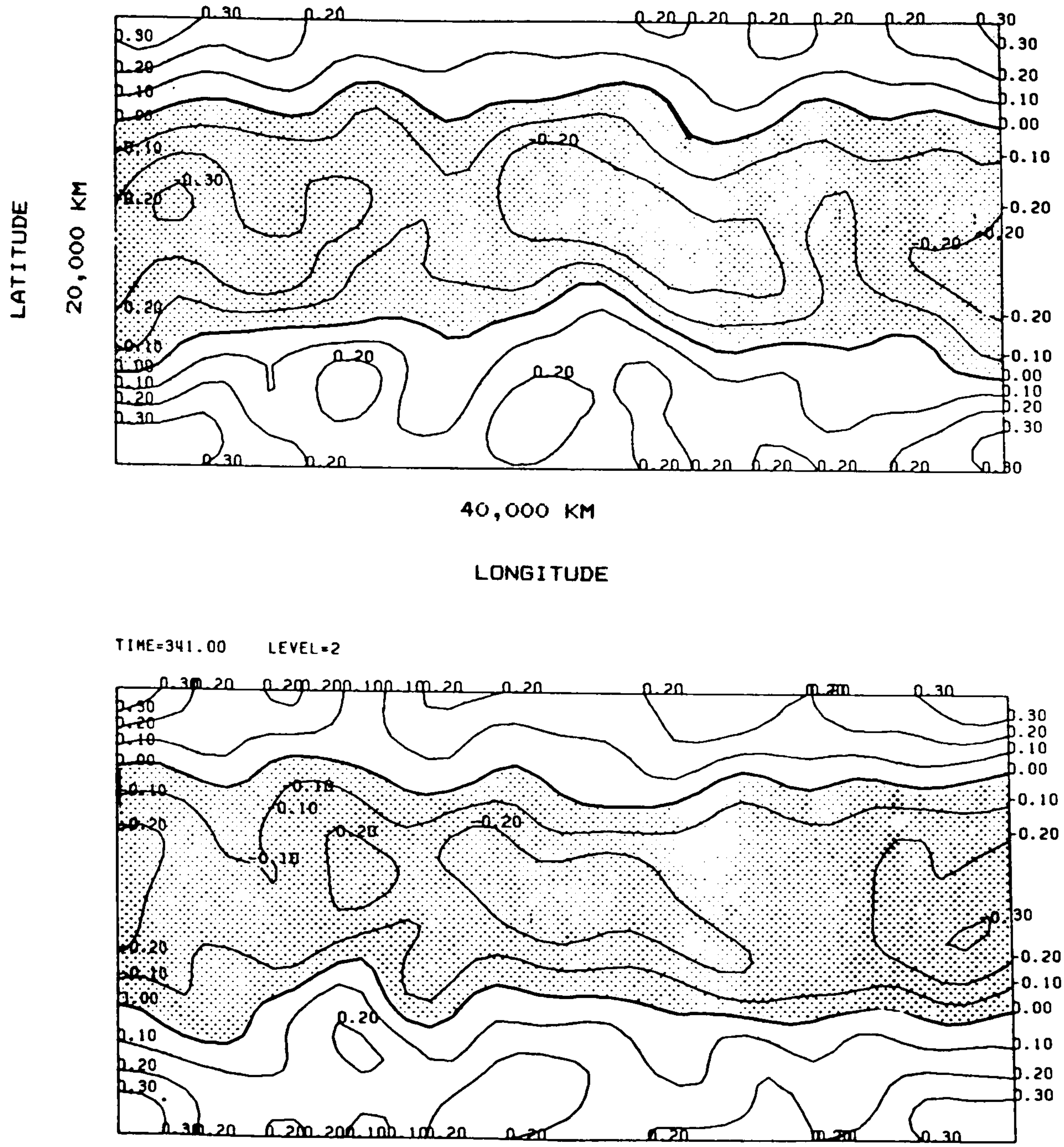

Figure 2. Stream functions for the case of S = 1.0 after "day" 1017 (top) and 1023 (bottom).

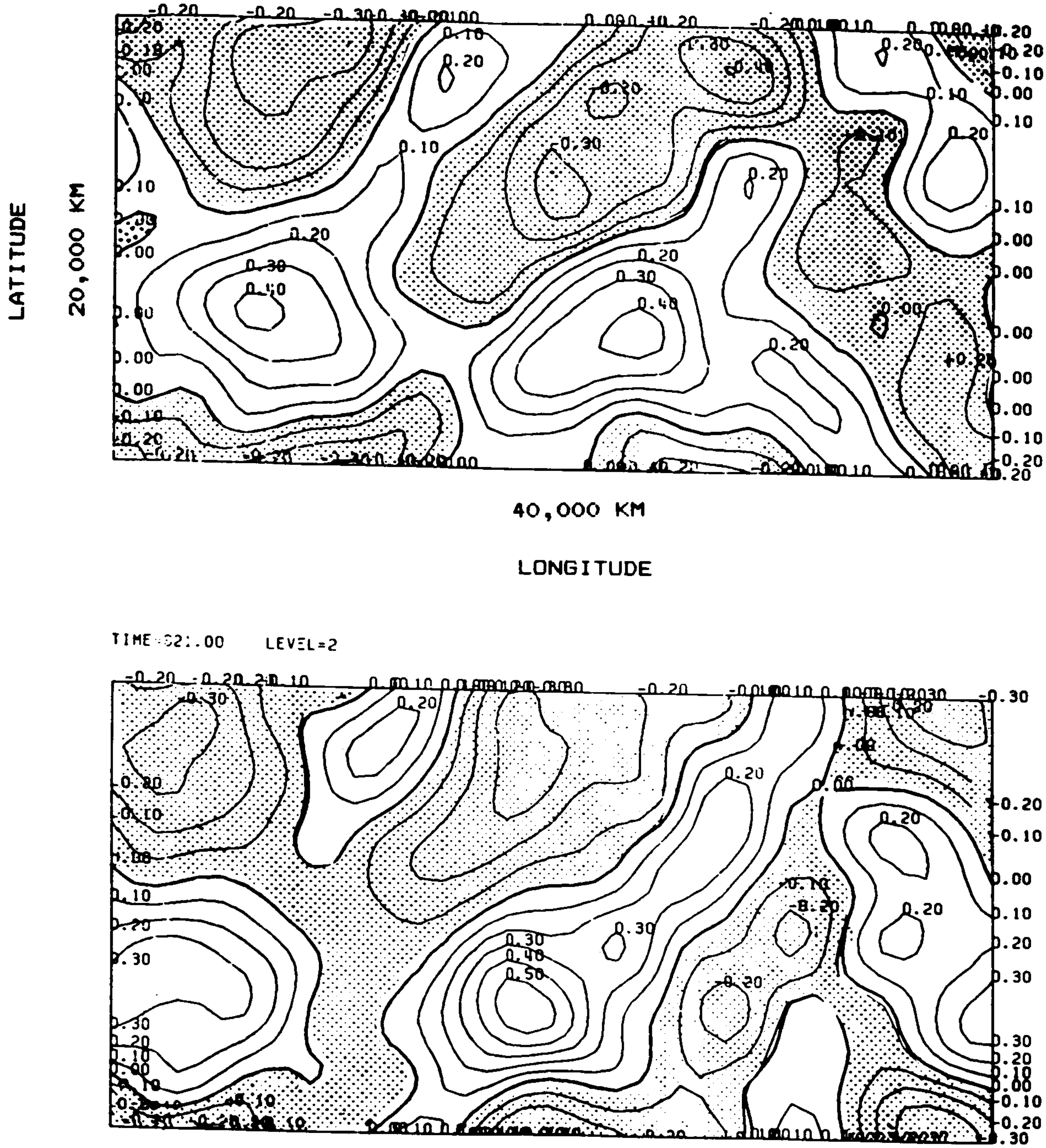

Figure 3. Stream functions for the case of S = 0.5 after "day" 957 (top) and 963 (bottom).

The results of the model experiments show that although the instabilities have exponential growth the nonlinear terms alone bound the solutions. (No explicit damping is required.) There is no equilibrium solution. The evolving zonal flow fluctuates and meanders by an amount dependent upon the parameter settings. The experiments also suggest that specific features propagate in the retrograde sense with respect to the mean flow.